APPLICATION OF PERMEABLE MATERIAL TECHNOLOGY FOR ENHANCED DRAINAGE DESIGN: FLOOD MITIGATION ALONG LA CONCEPCION COLLEGE PATHWAY TO HULO KABAN, BRGY KAYPIAN, SAN JOSE DEL MONTE, BULACAN

A Research Paper

Presented to the

Faculty of the College of Engineering

La Concepcion College

In Partial Fulfillment of the Requirement for the Degree

Bachelor of Science in Civil Engineering

Major in Construction Engineering and Management

Joanna Marie Braceros

Aldrin G. Geromo

Jemima B. Paulino

Lara Yvonne M. San Felipe

2026

RECOMMENDATION

This is to certify that this research entitled "APPLICATION OF PERMEABLE MATERIAL TECHNOLOGY FOR ENHANCED DRAINAGE DESIGN: FLOOD MITIGATION ALONG LA CONCEPCION COLLEGE PATHWAY TO HULO KABAN, BRGY KAYPIAN, SAN JOSE DEL MONTE, BULACAN", prepared and submitted by Joanna Marie Braceros, Aldrin G.Geromo, Jemina B. Paulino, Lara Yvonne M. San Felipe been examined and PASSED the PRE-ORAL DEFENSE.

ENGR. ELOISA P. CADAG, Reg. CE., MACT

Research Adviser

PANEL OF EXAMINERS

Examined and approved by the Panel of Examiners in a Pre-Oral Defense with a grade of _____ on November ___, 2025, at La Concepcion College, Bulacan.

Engr. WINIFREDO E. GONZALES

Chairman

Engr. CAROLINE A. ASUNCION

Member

Engr. CAMILO A. BATULAN JR.

Member

Accepted and approved in partial fulfillment of the requirements for the degree Bachelor of Science in Civil Engineering Major in Construction Engineering and Management.

ENGR. JORE GIL D. GALEZA

Division Head of Civil Engineering

LEILANI CUSACK, Phd, DBA

Dean of Instruction

CERTIFICATE OF ORIGINALITY

The researchers confirm that this research is their original work and has not been previously submitted or published. All sources and contributions have been properly cited, and the findings, analyses, and conclusions are the result of independent research.

Furthermore, the researchers declare that this study is free from plagiarism and has been conducted with honesty and integrity, although they received assistance and guidance from others. The researchers take full responsibility for the accuracy and authenticity of the content presented in this research.

Joanna Marie Braceros

Aldrin G. Geromo

Jemima B. Paulino

Lara Yvonne M. San Felipe

Attested by:

Engr. Eloisa P. Cadag
Research Adviser

Date: _____

TABLE OF CONTENT

Page

Title page i

Recommendation..... ii

Certificate of Originality iii

Table of Contents iv

List of Tables iv

CHAPTER I

The Problem and Its Background

Introduction 1

Background of the Study 2

Theoretical Framework 3

Conceptual Framework 4

IPO Conceptual Framework 5

Statement of the Problem 7

Objective of the Study 8

Hypothesis 9

Significance of the Study 9

Scope and Limitations 10

Definition of Terms 11

CHAPTER 2

Review of Related Literature

Foreign Literature 13

Local Literature 16

Foreign Studies 18

Local Studies 20

Synthesis of the Literature and Studies 23

CHAPTER 3

Research Methodology

Research Design 25

Sample And Population 25

Research Instrument 26

Properties of Materials 28

Data Gathering 30

Statistical Treatment …..... 31

LIST OF TABLES

Table 1

IPO Conceptual Framework..... 5

CHAPTER 1

The Problem and Its Background

This chapter provides an overview of the study, including the introduction, problem statement, theoretical framework, conceptual framework, study relevance, significance of the study, study scope and limits, and term definitions.

Introduction

In the Philippines, flooding is still a significant problem, in schools and communities, especially during heavy rains. At La Concepcion College, the pathway going to the Hulo Kaban Brgy. Kaypian, San Jose del Monte, Bulacan often collects water, making it hard and unsafe for students, teachers, staff and resident to pass. An efficient and sustainable flood control management system that can protect society from such calamities while reducing their negative effects on the environment and the economy is highly needed to solve this. One possible solution is the use of permeable materials. Unlike regular concrete or asphalt, these materials let water pass through the surface and soak into the ground. This helps reduce flooding, improves drainage, and makes pathways safer to use. This study focuses on applying permeable material technology to the pathway leading to the Hulo Kaban Brgy. Kaypian. It aims to find out how this design can lessen flooding, improve the safety of student and the resident, and promote sustainable construction practices.

Background of the Study

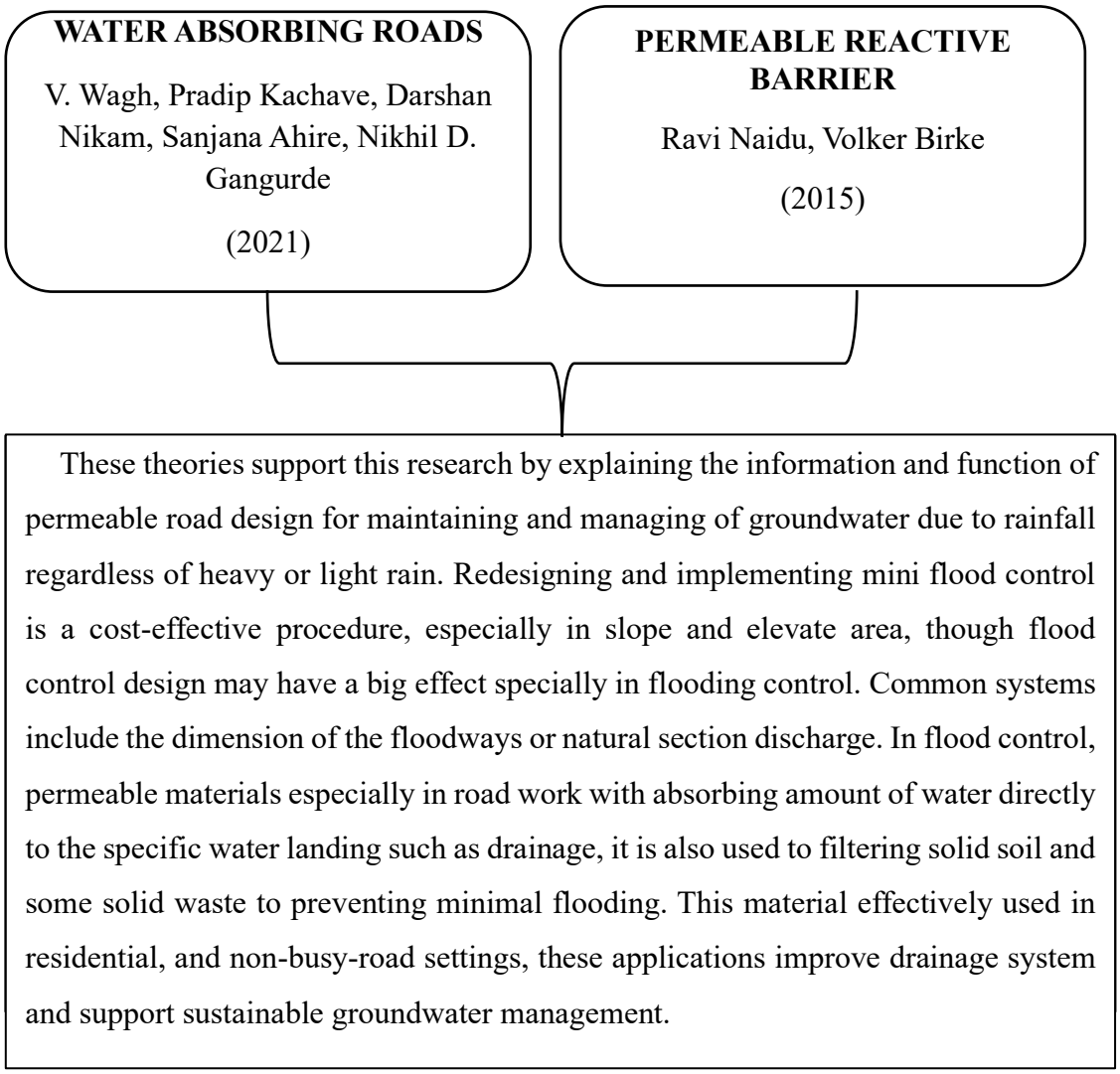
The Philippines experiences multiple rainfall every year. According to Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), an average of 20 typhoons a year fall upon the Philippines. This resulting in flooding on certain areas. The damages caused by this natural disaster is usually hard to predict as it is uncertain how strong or weak the typhoon is.

The improper drainage, combined with these topographical challenges, causes large-scale stagnant water, often making roads impassable. This not only disrupts daily life but also hinders emergency response and access to essential services. The accumulation of stagnant water also damages infrastructure.

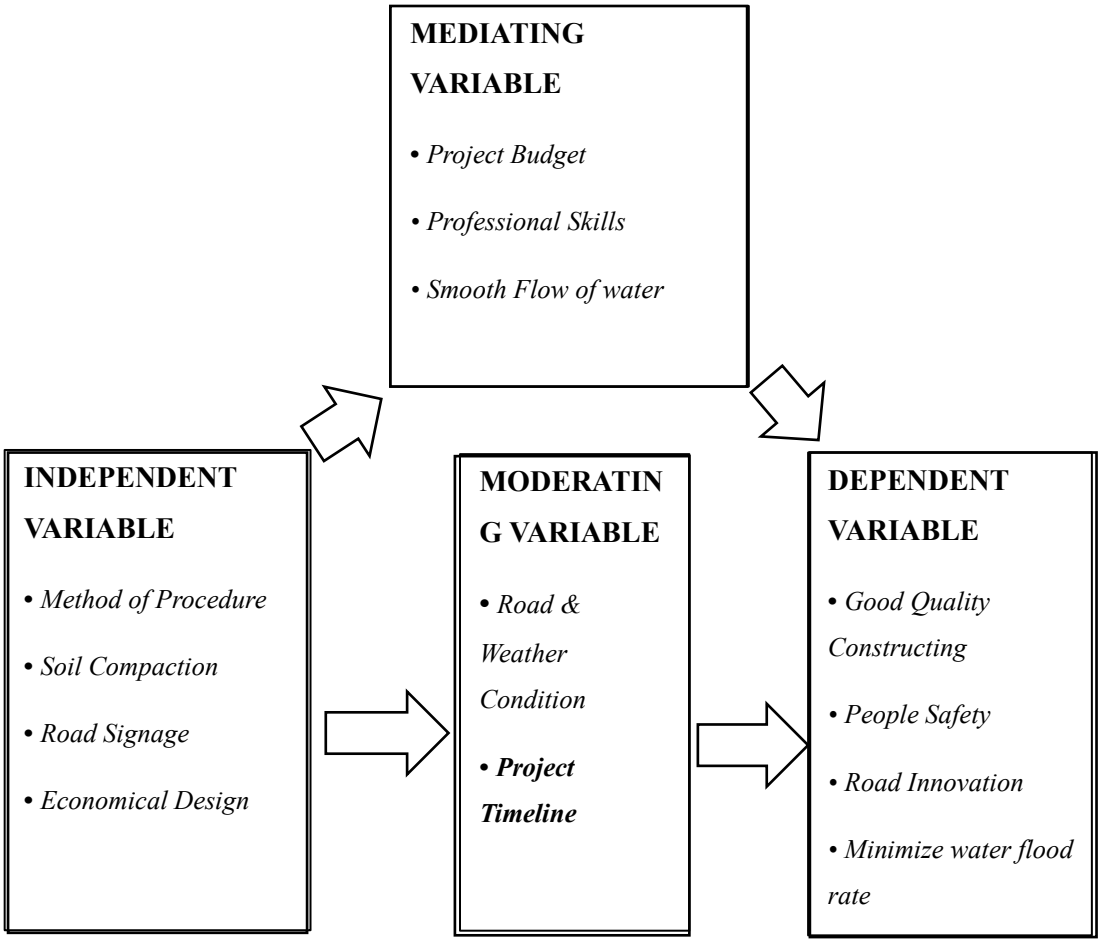
This study aims to address these drainage challenges by designing a sustainable flood control system that considers Hulo Kaban Brgy. Kaypian, San Jose del Monte, Bulacan, uneven roads, the researchers are looking to improve the pathway. The researchers are planning on using permeable material such that it allows water to pass through the exterior and absorbed by the ground. This not only help lessen the flood above surface, but it also replenishes the groundwater supply in the soil. By installing this porous material along the road of the CE building, the pathway will be safer for the students and decrease flooding.

Theoretical Framework

These theories serve as a foundation for understanding the development of research topics, and the interpretation of the results, this study mainly depends on them for direction and support. They make it possible to develop a strong theoretical framework that directs my research and expands our understanding of the field of study.


WATER ABSORBING ROADS
V. Wagh, Pradip Kachave, Darshan Nikam, Sanjana Ahire, Nikhil D. Gangurde
(2021)
PERMEABLE REACTIVE BARRIER
Ravi Naidu, Volker Birke
(2015)
These theories support this research by explaining the information and function of permeable road design for maintaining and managing of groundwater due to rainfall regardless of heavy or light rain. Redesigning and implementing mini flood control is a cost-effective procedure, especially in slope and elevate area, though flood control design may have a big effect specially in flooding control. Common systems include the dimension of the floodways or natural section discharge. In flood control, permeable materials especially in road work with absorbing amount of water directly to the specific water landing such as drainage, it is also used to filtering solid soil and some solid waste to preventing minimal flooding. This material effectively used in residential, and non-busy-road settings, these applications improve drainage system and support sustainable groundwater management.

Conceptual Framework



The Conceptual framework represents the relationship of the variables.

This conceptual framework studied the idea of improving the road design and enhanced drainage design: flood mitigation along the la Concepcion college pathway to hulo kaban brgy. Kaypian, San Jose del Monte, Bulacan, this framework offered a foundation for comprehending the potential variables and their potential relationships. The improvement of roadway safety and enhanced drainage design is the intervention in this instance, and it is anticipated that this will impact the student. It is anticipated

that the variables that fall between, in this case, road and drainage conditions, community knowledge, result in fewer and less severe accidents as well as a higher perception of road safety and drainage design among locals.

IPO Model Conceptual Framework

INPUT	PROCESS	OUTPUT
1. **How does the demographic profile of the respondents be measured in term of:** 1.1 Name 1.2 Occupation 1.3 Years of Stay /Association **2. How does the impact of rainfall intensity affect the community in terms of:** 2.1 water flow 2.2 volume of water	**• Data Gathering** **• Floodwater Management design analysis** **• Site Observation and Investigation of groundwater runoff** **• Surveys and Questionnaires** **• Calculating the collected data** **• Data Analysis using Statistical tools**	1. A condition report of the current drainage system, identifying weaknesses and inefficiencies that lead to water accumulation and flooding.

3. How can the application of permeable enhance the drainage design along the La Concepcion College to Hulo Kaban, Brgy. Kaypian, San Jose del Monte, Bulacan.

pathway in terms of:

3.1 Accessibility

3.2 Safety

3.3 Sustainability

4. How effective does the design and installation of permeable pathway be assessed in terms of:

4.1 cost-effectiveness

4.2 lifespan

4.3 durability

2. A system performance assessment discussing the advantages of the new system based on engineering principles, such as better water flow and enhanced flood control efficiency

3. A detailed design plan of an permeable pavement including its size, capacity, position, and water discharge system.

The Conceptual framework represents the transformation of materials and data into output

Statement of the Problem

In this study, the researchers aim to determine the efficiency of roadway safety and a drainage system for flood management at La Concepcion College to Hulo Kaban, Brgy. Kaypian, San Jose del Monte, Bulacan.

Furthermore, the researchers seek to answer the following questions:

1. How does the demographic profile of the respondents be measured in term of:

    1.1 Name

    1.2 Occupation

    1.3 Years of Stay/Association

2. How does the impact of rainfall intensity affect the community in terms of:

    2.1 water flow

    2.2 volume of water

3. How can the application of permeable enhance the drainage design along the La Concepcion College to Hulo Kaban, Brgy. Kaypian, San Jose del Monte, Bulacan. pathway in terms of:

    3.1 Accessibility

    3.2 Safety

    3.3 Sustainability

4. How effective does the design and installation of permeable pathway be assessed in terms of:

    4.1 cost-effectiveness

    4.2 lifespan

4.3 durability

Objective of the Study

The researchers aim to achieve the following objectives to assess the effectiveness of an application of permeable material technology for enhanced drainage design: flood mitigation along the La Concepcion College pathway to the Hulo Kaban, Brgy. Kaypian, San Jose del Monte, Bulacan. To evaluate the current state of the road and the drainage system of the pathway to Hulo Kaban.

1. Determine the demographic profile of the respondents to understand community characteristics that may influence perception and impact assessment, in terms of:

- Name
- Occupation
- Years of Stay/Association

2. Analyze the effects of rainfall intensity on the surrounding community and drainage system performance in terms of:

- Water flow dynamics
- Volume of surface runoff

3. Evaluate how the application of a permeable pathway can improve the drainage design along the La Concepcion College to Hulo Kaban corridor in terms of:

- Accessibility
- Safety

- Sustainability

4. Assess the overall effectiveness of the proposed permeable pathway design and installation in terms of:

- Cost-effectiveness
- Lifespan
- Durability

Hypothesis

Null Hypothesis (Ho): The residents, students at La Concepcion College, and those living in Hulo Kaban Brgy. Kaypian, San Jose Del Monte, Bulacan does not feel that anything has changed in the current road and drainage design and construction compared to the previous.

Alternative Hypothesis (Ha): The resident, students at La Concepcion College, and those living in Brgy. Kaypian, San Jose Del Monte, Bulacan, feels that anything has changed in the current road and drainage design and construction compared to the previous.

Significance of the Study

This research could prove valuable to the people and provide useful and significant insights that could be of great help to the following:

Students. This study provides a solution to flooding issues, improving the safety of the students. It ensures the protection of properties, and infrastructure from flood damage. This study can help the students gain knowledge on how permeable material can be applied in real-life situations, helping them connect classroom theories with sustainable engineering practices.

Inhabitants. This study can improve the residents of Brgy. Kaypian and nearby areas, frequent flooding and poor roadway drainage. The application of permeable materials aims Improve the drainage efficiency, not only promotes safety and accessibility during rainfall events but also contributes to long-term community resilience.

Local District Authorities. the study may serve as a reference in developing flood mitigation strategies and adopting eco-friendly infrastructure solutions in the community.

Future Researchers. this study can provide baseline information and insights that can be expanded through further studies on drainage design, material testing, and sustainable construction practices.

Scope and Limitations

This study focuses on the road and flooding problem along the pathway leading to Hulo Kaban, Brgy. Kaypian San Jose Del Monte, Bulacan. It will explore the use of permeable material technology as a possible solution for improving drainage design

and reducing water accumulation in this specific area. The study will gather insights from students and residents about their experiences with flooding and their views on the use of permeable materials. The study will use both quantitative and qualitative methods such as interviews, focus group discussions, and observations. It includes laboratory testing of the physical properties of permeable materials, cost analysis, but not actual construction of the design. The coverage is also limited to the specific street and will not address flooding issues in other areas of brgy. Kypian. The recommendations provided are intended to serve as a conceptual basis for future planning and not as a final engineering implementation plan.

Definition of Terms

These are the words that may help this study be more understandable.

Drainage System - It is a network designed to collect, transport, and dispose of excess water or wastewater.

Enhancing - to increase or improve in value, quality, desirability, or attractiveness.

Flood control - It is the prevention or management of flooding.

Groundwater - water within the earth especially that supplies wells and springs

Mitigate - Means to reduce the severity, seriousness, or impact of something, such as a problem or negative situation.

Permeable - having pores or openings that permit liquids or gases to pass through

Porosity - The measure of void spaces within a material, typically expressed as a percentage, which determines its ability to absorb and transmit water.

Surface Runoff - The excess water flow that occurs when precipitation exceeds the infiltration capacity of the soil or pavement, often leading to pooling or flooding.

Sustainable. Refers to the ability to meet present needs without compromising the ability of future generations to meet their own needs, often by balancing environmental, social, and economic considerations.

Topography. refers to the detailed surface features of an area, including its elevation, terrain, and the arrangement of natural and man-made features.

CHAPTER 2

Review of Related Study and Literature

This chapter presents a review of related literature and studies, following a thorough search done by local and foreign researchers. Those included in this aid familiarizing with relevant and similar information to the current study Application of Permeable Material Technology for Enhanced Drainage Design: Flood Mitigation along the La Concepcion College Pathway to Hulo Kaban, brgy. Kaypian, San Jose Del Monte, Bulacan.

Foreign Literature

According to Lee, Y.-T., et al. (2023). More highways need to be built because Taiwan is still in the urban development stage. Thus, one of the main challenges at hand is figuring out how to lessen the environmental impact of road engineering. As a result, a general pavement and permeable pavement demonstration road was constructed on Dahua North Street in Taoyuan City, Taiwan. Using an inventive construction technique, rainwater was collected in a central irrigation ditch and permeable pavement for later use in agricultural irrigation. A field-monitored study that reported a ~60–75% reduction in peak discharge for permeable pavement compared to conventional pavement, supporting the use of permeable systems for urban flood-peak mitigation.

According to Sousa, M. (2024). In the words of Sousa, M. (2024). Permeable asphalt pavement (PAP) is a powerful solution to stormwater management that allows

water to percolate through it. It reduces runoff from the surface and lowers urban flooding risks. This review discusses various matters concerning PAP. The rapid urban expansion linked to the migration of people to cities has resulted in a steady rise in soil sealing. The extensive growth of urban regions is a primary factor in the significant transformation of the hydrological cycle. Implementing Sustainable Urban Drainage Systems (SUDSs) aims to alleviate flooding problems by controlling stormwater within urban areas.

According to Yang, Q., et al. (2022). An important source control component of low-impact development, sustainable drainage systems, water-sensitive urban design, and the Chinese Sponge Cities initiative is the infiltration of stormwater runoff. By allowing stormwater runoff to flow through their surface, pervious concrete pavements also absorb pollutants. Pervious concrete pavements have a porous structure that allows water infiltration and the evaporation of some infiltrated stormwater, in contrast to non-permeable asphalt and concrete surfaces. Pervious concrete pavements therefore contribute to improved flood control, improved water quality, and reduced urban heat island effects. Permeable interlocking concrete pavers (PICPs), which permit stormwater to percolate through the spaces or gaps between the pavers, and porous concrete are the two main types of pervious concrete pavement systems.

According to Liu, L., et al. (2025). An impermeable surface, traditional concrete pavements do not breathe or absorb water like natural soil; hence, casing several environmental issues including urban heat island effect, flood problems, and

stormwater runoff pollution. To counteract increasing climate change challenges and urban resilience-increasingly felt are the incidences and severity of heavy rainfall events-the concept of sponge cities has received much global attention. Sponge Cities are offering the kinds of urban water management that will harness both natural and engineered systems for capturing, retaining, and purifying rainwater and therefore reducing its risks associated with floods and increasing the resource's sustainability. Nature-Based Solutions (NbS) have been incorporated within the global landscape of these city infrastructures, including in Europe, North America, and Asia, in the programs that use nature-based means to cope with the climate impacts. This calls again for a new ideology promoting innovation-based development, environmental sustainability, and technological advancement integration in city planning. Developing sponge cities can help solve local environmental problems and creates a global initiative for carbon neutrality and improved urban resilience. Globally, cities can better manage the unpredictable nature of climate change to better the quality of life for its residents, and sponge cities approaches encourage sustainable urban water management. The overall efficacy of permeable concrete will depend on its aggregates' physical and mechanical properties, the cement paste, and the arrangement of pore space.

Permeable Interlocking Concrete Pavements: hydraulic and structural performance. According to **Moretti, L., et al. (2025).** As an essential element of sustainable urban drainage practices (SuDS), they effectively control surface water by capturing runoff, decreasing its quantity, and aiding in water treatment prior to its

return to the ecosystem. Permeable pavements are a type of sustainable pavement which is a layer of crushed stone or gravel which water will permeate through by filling up the void spaces between the stone particles which provides the water penetrable surface. These surfaces are primarily for pedestrian use and normally have an acceptable level of service. Permeable Interlocking Concrete Pavements (PICPs) have arisen as a porous paving solution, significantly minimizing runoff and enhancing water quality. This research examines the foundational depth for PICPs in relation to their strength and permeability. This research analyzes the hydraulic and structural behavior of Permeable Interlocking Concrete Pavements (PICPs) in urban and industrial settings by assessing the impacts of subgrade conditions, traffic loads, and material characteristics.

Local Literature

The study "Permeable Pavement for Sustainable Stormwater Management Using SWMM," conducted by **Al Patrick Castro and colleagues in 2023**, found that the enhancement of urbanization in the Philippines transformed natural lands into inadmissible surfaces and contaminated runoff surfaces. Using the Low Impact Development (LID) technologies for the alternative unlike the conventional drainage system. Reduction of stormwater runoff and treatment of massive stormwater are the focus of the study. According to the research, the permeable pavement is capable to

infiltration, reducing the clogging of solid waste, which is favorable for long-term stormwater management and flood control plans.

According to a study by **Ricky Boy D. Ramos et al (2023**). The most oftentimes weather-related natural disasters are floods. Floods around the world have often been a major hazard to and delay in the growth of human habitats and the environment. The impacts of a flood vary according to a number of elements, including the length, depth, size, and velocity of the flood, as well as environmental hazards, the importance of the situation, and the structure's relevance. Nowadays floods may take days or more to affect people, communities, society, the economy, and the environment. Because of poor road and drainage infrastructure, Parian, Mexico, Pampanga, is one of the areas that frequently experiences flooding. When it comes to stopping stormwater flow, permeable concrete is a great substitute for conventional concrete. By permitting surface water to freely pass through the worn surface and into the earth underneath it, permeable concrete can act as a reservoir during periods of intense precipitation.

According to **Alcantara (2019)**, drainage problems are also a problem in the Philippines. Floods may result from a combination of factors, including inadequate community drainage and overburdened river systems brought on by growing urbanization, in addition to the intensity of monsoon rains and 16 typhoons. So, we may say that there are always problems with drainage systems and floods in the area as the population grows.

According to **Kim Chester M. Castro et al. (2023)**, stated that flooding has a major impact on a community in regard to safety and health. As a result, this issue requires suitable solutions. Locations such as Santa Catalina, Lubao Pampanga, also faces the same issue due to its natural landscape. This increases the risk of contamination and flooding. This increases the risk of dangerous illnesses. As a solution for maintaining a surplus of water in its sub-base layer, use of permeable pavement can reduce the risk of flooding and improve environmental cleanliness at Don Honorio Ventura State University's Lubao Campus.

According to the study by **Lemuel Manalo (2017)**, using standard concrete and asphalt in road design has ecological disadvantages, including flooding, higher ambient heat, and pollution sequestration obstruction. The researcher concludes that the permeable paving is the best choice since it allows stormwater to drain into the ground. The National Building Code of the Philippines allows for larger impervious areas within lots. A study surveyed five enterprises in Davao City to evaluate the performance of permeable pavements and recommend acceptable usage under various conditions, particularly for PWD access. According to the report, municipal policy should integrate permeable pavements in building codes.

Foreign Studies

According to **Liu Q., et. al. (2024)**, urbanization has been forging ahead in the times producing in the expansion of concreate roads. This resulting in the obstruction of the natural percolation and unto urban flooding. This brought up the concept of

developing “Sponge Cities” in China that naturally accumulate, permeate and purify rainwater. Permeable concrete is a commonly used material in establishing the sponge cities. This study shows that permeable concrete blocks made from graded gravel increases its porosity. The higher the proportion of smaller particle sizes, the lower the porosity and permeability of the coefficients of the blocks. (Liu et. al., 2024)

According to **Awan A.R., et.al (2025)**, Pakistan has been susceptible to flooding, especially in the lowlands. The research studies the use of permeable concrete pavements as a sustainable way of reducing flooding. The results show that permeable concrete improves the water penetration to the soil and lessen the surface runoff. Implementing these improvements allow the urban areas to have protection against flooding.

According to **Nelson K. (2025)**, urban flooding has been a challenge in Huancayo, Peru. This study aims to develop an innovative solution for urban flooding by creating a permeable concrete mixture using agave and bamboo. These materials are used to enhance efficiency and structural integrity of the concrete. The results showed that the mixture of agave and bamboo fibers enhanced the mechanical strength and permeability of the concrete. The ideal mixture is consisted of 0.8% agave fibers and 0.4% bamboo fibers. It reached a compressive strength of 242.06 kg/cm² and a permeability of 1.167 cm/s.

In the study of **Barua G, et. al, (2024)**, permeable materials are environmentally beneficial in flood control in urban areas. High-strength pervious

pavement was used in this study. Adding polypropylene fiber reduces the compressive strength but increases the split tensile strength, degradation and potential resistance of the concrete. The results showed the wide range of use of the reinforced high-strength pervious material. It will enhance and improve the ability to counter urban flooding.

In the study of **Puspitasari, S.D., et. al. (2023),** urban roads in Jakarta have been affected by flood due to excessive surface runoff. Majority of the pavement installation in Jakarta has been the standard pavement that is ineffective against draining rainwater. This study analyzed porous asphalt, pervious concrete, and interlocking concrete pavers. Among these three pavements, the study shows that permeable pavement reduces the more rainwater than standard pavement. Porous asphalt is the most likely to be implemented in the roads of Jakarta especially in light traffic.

Local Studies

Assessment of the Feasibility of Permeable Pavement for Sustainable Stormwater Management Using SWMM (Storm Water Management Model) De La Salle University (Sinaya journal). **Castro, A.P.C., et al. (2023).** The increase in urbanization in the Philippines has altered natural landscapes and changed the land to impermeable surfaces, resulting in the pollution of surface runoff and nearby bodies of water. Low Impact Development (LID) strategies were recommended as a replacement for drainage systems, especially with permeable surfaces. The implementation of this technology allows for reduced stormwater runoff, increased

stormwater Infiltration into the ground, and the treatment of stormwater. This study evaluated the effectiveness of permeable pavement, as a type of stormwater management practice, in a university environment at De La Salle University Laguna Campus. The results from this study demonstrated that permeable pavement could support infiltration, reduce surface runoff volume, and store surface runoff, which can facilitate more sustainable, long-term stormwater management practices and flood mitigation efforts.

Design of Permeable Pavement and Underdrain in Don Honorio Ventura State University **According to (IJSRED, 2023).** Created a solution that combines permeable pavement with an underdrain system for a Pampanga campus location where subgrade infiltration was anticipated to be restricted. the engineering design provided sizing guidelines and operational advice, illustrating a practical local approach when complete exfiltration to natural soils is not possible (DHVSU design, 2023). In a similar vein, a community-based project proposal for Parian, Mexico, Pampanga (Ramos et al., 2023) outlined a permeable concrete road and drainage system as a flood-mitigation strategy tailored for a barangay setting; though more a design/proposal than a long-term monitoring initiative, it illustrates municipal engagement and local engineering adaptation.

Supporting these practical studies, **Cameon et al. (2022)** from best link College of the Philippines proposed a conceptual project regarding the application of pervious concrete in local road systems. While primarily exploratory, the research positioned pervious concrete as a cost-effective, community-based solution for reducing flood risks. The researchers examined possible material sources, such as local aggregates, and emphasized advantages like decreased surface runoff, improved groundwater recharge, and alleviation of urban heat islands. Though less data-driven than the work of Castro or Mejia, this proposal adds to the increasing recognition of permeable pavement technology within academic discussions. It likewise demonstrates the function of higher education organizations in fostering awareness and promoting initial design concepts tailored to urban settings in the Philippines (Cameon et al., 2022)

Pagbilao (2021) studied porous asphalt concrete mixtures at the University of the Philippines Diliman and assessed the impact of various porosity levels on Marshall Stability and structural performance. The author mentions a trade-off between permeability and stability, with increased void contents improving drainage but decreasing load potential. Trade-offs such as this show the need to balance hydraulic performance and structural integrity where porous asphalt is used in a Philippine context. Pagbilao's results are especially applicable to pedestrian pathways where load requirements are fair, but the risk of blockages is significant due to fine sediment and tropical waste.

Appropriate gradation and binder levels can provide adequate strength while preserving infiltration ability (Pagbilao, 2021)

Reyes, Quiambao, Guintu, et al. (2022) investigated the impact of aggregate shape, size, and water-to-cement ratio on the compressive strength, permeability, and abrasion resistance of pervious concrete—essential for walkways subject to foot traffic (Reyes et al., 2022). where wear resistance is equally important as hydraulic efficiency. Moreover, although not extensively available, CEMEX Philippines's "Aquacrete" permeable concrete (2016)—which includes small openings and supports weight—shows the private sector's ability and willingness to adopt permeable technologies in the local market (CEMEX, 2016). Impermeable concrete frequently exacerbates flooding in the Philippines since it inhibits the natural absorption of runoff into the soil. An attractive remedy for this issue is the use of pervious concrete, which features a high void ratio that enables water to flow through it.

Syntheses of the Study

Flooding has been common due to usage of standardized concrete pavements. The rapid urbanization had contributed significantly on the frequent flood events. Studies shows that permeable concrete is effective against reducing surface runoff. China has implemented the use of permeable concrete in their urbanization project of Sponge Cities. It was shown that permeable concrete made from graded gravel increases its porous property. A study in Pampanga, Philippines

has created a solution combining permeable concrete and underdrain system in their school's campus, although the design provided with the practical approach when complete exfiltration to natural soils is not possible. A few of the studies shows that the usage of permeable concrete has significantly reduced the surface runoff and increased the water penetration to soil improving urbanization projects. This study aims to improve the drainage design for flood mitigation for the pathway to the Hulo Kaban Brgy. Kaypian, San Jose del Monte, Bulacan. The study focuses on using permeable concrete materials to improve drainage and makes the path safe for the LCCians and Residents to walk through. Using the related studies and literatures for improving the flooding mitigation and using the data to improve existing permeable materials. This study aims to improve the drainage design for flood mitigation for the pathway to the Hulo Kaban Brgy. Kaypian, San Jose del Monte, Bulacan.

CHAPTER 3

Research Methodology

This chapter presented the research design, population, research instrument, data collection procedure, and data analysis of this study. These methodologies served as guidelines for the proponents in conducting the relevant procedures needed from the collection to the analyses of data.

Research Design

An Explanatory Mixed Method Design was used because both Quantitative and Qualitative research designs were considered most appropriate for this study. Address existing issues of the road and drainage system in Hulo Kaban, Brgy. Kaypian, San Jose del Monte, Bulacan. The descriptive approach focuses on collecting data, analyzing and collect an opinion to the flood problem, drainage performance, and rainfall level, determining the main causes of floods and stagnant water using data analysis. The developmental approach concentrates on creating, evaluating, and refining a solution considering the descriptive approach's findings. This combination of research designs will provide precise insights into the effectiveness of the proposed Permeable material technology for enhanced drainage.

Sample and Population

The target population for this study will be the residents of Hulo Kaban Brgy Kaypian, San Jose del Monte, Bulacan, specifically those living along the said street

and those students at La Concepcion College that were walking along that pathway, as they are the primary stakeholders in the present road and drainage infrastructure. Using a simple random sampling strategy will be used to selecting respondents, ensure that every resident has an equal opportunity of being included in the study. The total sample size will be 150 respondents, which is considered sufficient given the area's population size. This sample size will help assure that the results are statistically significant and representative of the community's opinions.

Research Instrument

This study used questionnaires to survey residents in the area, particularly students and residents, regarding the effects of conventional roads. The questionnaire was developed based on the study's objectives. The questionnaires consisted of thirty (30) items and included respondents' basic personal data and the suggestions and comments.

The first part of the questionnaires consisted of three (3) questions about the personal data or basic information of respondents, and the second part A consisted of five (5) questions about the Road Condition History using Likert Scale, and the B part of the questionnaires consisted of five (5) questions about the Flooding Frequency and Duration and it is also using Likert Scale method, the C part was consisted of five (5) questions, and it is all about the e. Impact of Flooding on the LCC Community, the D part was consisted of five (5) questions, and it is all about the Community Awareness and Response. and the E Part consisted of five (5) questions that express the Perceived

Need for Permeable Pavement and lastly, Part III we will ask a simple question to gather other's opinion about the road and drainage conditions along the said street

In terms of design and planning, the researcher uses AutoCAD for creating and designing isometric and two-dimensional (2D) digital models and to visualize the road pavement safety features in Sitio Hulo Kaban Road. Also use Google Maps and Wikimapia for gathering some data in terms of the exact coordinates and barangay, and to know the length of the location, the researcher used a measuring wheel, or in other terms, a wheel meter.

a. AutoCAD

A powerful computer-aided design (CAD) software primarily used for creating and editing 2D and 3D technical drawings and models.

b. Data Analysis

Quantitative method that allows the researcher to examine and interpret information

c. Map or Scaled Model

The location, size, and topography of the area will be needed in the study.

d. Regression Analysis

To determine how different factors affect flood levels in the area.

e. Sketchbook

An easy-to-use tool for digital sketching and painting, offering both beginners and professionals a platform to bring creative ideas to life. The researchers will be using this app to sketch and draw the design of the study.

Properties of Materials

• **Permeable Concrete - (Thickness: 50–100mm) -** A high-porosity material used in concrete flatwork applications allows water from precipitation and other sources to pass directly through, thereby reducing runoff from the site and facilitating groundwater recharge.

• **Coarse aggregate -** In a permeable pavement system, aggregate is one of the main layers that provides both drainage and structural support, especially in permeable pavement roads. 4.7 mm diameter coarse aggregate particles or No. 4 sieve will allow water to easily pass through the pavement surface and infiltrate into the underlying soil. It also helps to reduce surface runoff and prevents flooding.

• **Crushed stone / Angular rock (Rock size 20mm diameter) -** It is also permeable pavement base layer should be clean, angular, and well-graded to ensure both structural stability and effective drainage performance, it is also providing additional structural strength and drainage capacity.

• **Geogrid -** This will serve to separate the subgrade and aggregate layers, especially the crushed stone, and it will prevent soil contamination and also improve the load

distribution. Included in it are the high tensile strength, permeability, and resistance to road degradation, which ensure the structural stability. It can also carry 10-40 kN/m tensile strength.

• **Non-woven Geotextile -** This is usually used in the permeable pavement road system and serve as a separation and filtration layer between the subgrade and the aggregate layer; this is usually installed together with geogrid. These materials are made of polypropylene fibers. That material provides high permeability and tensile strength. Geotextile thickness ranges from 0.5 mm to 3.0 mm depending on the road situation. In terms of tensile strength, geotextile is usually the same as geogrid, with up to 10 kPa to 40 kPa. One of the main functions of non-woven geotextile is to help prevent soil migration while allowing water infiltration.

• **PVC perforated pipes -** This will serve as the drainage conduit in the permeable pavement road. It is made of unplasticized polyvinyl chloride, also known as uPVC, which provides excellent durability, chemical resistance, and structural strength. These are usually 100–150 mm in diameter with perforations of 5 mm to 10 mm for water draining, allowing water collected from the pavement layers to flow and infiltrate into the subsoil or outlet system. The tensile strength of PVC perforated pipes is in the range of 45 MPa to 55 MPa, and the compressive strength is in the range of 45 MPa to 80 MPa to ensure stability under vehicular loads while maintaining long-term hydraulic performance. PVC perforated pipes are also excellent in terms of carrying acids and salts.

• **Natural soil or Compacted soil -** This will serve as the subgrade foundation of the permeable pavement road system. It provides structural support while allowing limited water infiltration. Typical properties include a permeability of 0.010–0.00010 m/s, a load-bearing capacity of compacted soil with a range of about 5–15%, and relative compaction between 85–95% of maximum dry density.

Data Analysis Method

After data collection, the researcher submitted a request for a letter of approval to the Engineers for approval and standardization of the questionnaire's procedure. Once approval was obtained, the researchers used the instrument with study participants. At the same time, the authors interviewed community residents regarding the quality of the road and drainage mitigation along the La Concepcion College pathway to the Hulo Kaban, Brgy. Kaypian, San Jose del Monte, Bulacan to understand the key issue to be resolved. The researcher also interviewed respondents and collected pertinent data regarding safety Features in roadway The researchers also had a proper formal request and permission from the Barangay kaypian. The results that were gathered from the questionnaire survey were tallied, organized, validated, and analyzed. To ensure the integrity of the results, it is reviewed and validated by the research advisers of the study. The mean score of the results is computed in the Likert scale data. It is obtained by summing the scores per question and divided by the number of participants. Then it will be assessed to the most frequent response and

check the variability of the responses. The results were used to modify and alter the requirements or necessity of the pathway.

STATISTICAL TREATMENT OF DATA

Descriptive Statistics

Descriptive statistics were used to summarize and interpret the data gathered from the respondents. The following tools were employed:

Frequency and Percentage Distribution

This was used to describe the demographic profile of the respondents in terms of their occupation and years of stay or association with La Concepcion College and Hulo Kaban, Brgy. Kaypian.

$$P = \frac{f}{N} \times 100$$

where:

P= percentage

f= frequency of responses

N= total number of respondents

Weighted Mean

This was used to determine the respondents' level of agreement on the indicators related to road condition history, flooding frequency and duration, impact on the community, community awareness and response, and perceived need for permeable pavement.

$$\bar{X} = \frac{\sum(f \times x)}{N}$$

where:

f= frequency of each rating

x= scale value (1–5)

N= total number of responses

The verbal interpretation of the weighted mean was based on the following scale:

Scale Range	Verbal Interpretation	Rate
4.21 – 5.00	Strongly Agree	5
3.41 – 4.20	Agree	4
2.61 – 3.40	Neutral	3
1.81 – 2.60	Disagree	2
1.00 – 1.80	Strongly Disagree	1

Qualitative Analysis

Analysis of open-ended responses in Part III of the survey was conducted through **Thematic Analysis**. Suggestions or ideas with similar meanings were merged into collective themes like "improved drainage", "better maintenance" and "use of eco-friendly pavement". Then the occurrence of each theme was counted to discover the most popular proposals.